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ABSTRACT

Included are results of a study conducted to assess the possibilities and effectiveness of learning physics at high school level via independent study. The sample was drawn from a regular high school physics class. During the experiment, no instruction was carried out by any teacher. An auto-instructional system was developed and provided for use by students. Materials included lesson guides, cassette tape recordings, flip-card presentations, and chapter tests. The unit covered during the treatment was selected from Project Physics curriculum materials which were in use in the school. The students had access to a room with independent and movable carrels. Pre-test scores were found to be slightly below the national norms. The post-test scores on the unit learned during the experiment were slightly higher than the national norm. The experiment was supervised by a non-science proctor who was responsible for coordination and checking the materials in and out to students. Self evaluations after each topic were regarded by students as very helpful. The student opinion survey, however, revealed that students preferred instruction by a physics teacher rather than through the auto-instructional approach. (PS)

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Final Report

Project No. 1-D-026
Grant No. OEG-4-71-0038

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Calvin Bolin, Principal Investigator
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A MODEL FOR IMPLEMENTING THE PROJECT PHYSICS COURSE FOR INDEPENDENT STUDY

September 15, 1972

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development

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Author's Abstract

This is a report on a study designed to determine the feasibility of implementing Project Physics on an independent study basis using multi-media materials individualized according to students' interests and needs. Supplementary materials for Unit 3, The Triumph of Mechanics, were prepared and tested in a pilot project at the University School of Florida State University where a proctor (non-physics teacher) supervised the students participating in the study.

Supplementary materials featuring lesson guides, audiotapes, self evaluations, and chapter tests were designed in such a manner as to require a minimum of additional or procedural instructions. All instructional materials and procedures were administered by the proctor.

The materials devised for the study were evaluated formatively and summatively. The summative evaluation was based on the Project Physics Unit Tests. The experimental class performed above the national norm on the Unit 3 test after study of the Unit using the supplementary materials under the supervision of the proctor.

Opinion surveys completed by the students showed that the overall class reaction to the format of the materials and related usefulness did not appreciably change during the study; however the students did indicate a preference for a class taught by a qualified physics teacher.

The results suggest that a Project Physics course using supplemental materials similar to those developed for this project can be implemented for independent study and that students will achieve as well as if they studied the course with the help of a qualified physics teacher.

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U.S. DEPARTMENT OF
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INTRODUCTION:

This report describes the materials developed to supplement one unit (Unit 3, The Triumph of Mechanics) of the Project Physics Course as a model for redesigning the whole course for independent study. The materials were developed and tried in a pilot project under conditions similar to those envisioned for their eventual use. The results of the pilot tryout are also included in this report. The objectives of the project were: (1) to develop the necessary supplementary materials to implement one unit (four chapters) of the Project Physics Course on an independent study basis using multi-media materials and individualized according to students' interests and needs based on self evaluation, (2) to evaluate the effectiveness of these materials and make the appropriate revisions of this unit so it can serve as a model for a large scale effort to implement the complete Project Physics Course on an independent study basis, (3) to write a proposal for the purpose of obtaining funds for developing and evaluating materials for implementing the entire course on an independent study basis.

RATIONALE:

The rationale for proposing this project was that numerous students are deprived of the opportunity to enroll in a high school physics course because of the acute shortage of qualified high school physics teachers. This shortage of qualified teachers may have an effect in several ways. Some schools, particularly small rural schools, offer no high school physics course at all because of the inability of the school system to obtain a teacher capable of teaching physics. Other schools have a part time physics teacher - part time in that only part of his teaching load is physics. Generally this person's major interest is in another content area and he does not give priority to the physics program. He generally lacks enthusiasm for teaching physics and covertly hinders the enrollment of students in physics. A purpose of this project was to provide a means for students to study physics without dependence upon a qualified physics teacher; a non-physics teacher would be used to manage the course.

It was also envisioned that a qualified physics teacher could use the materials produced to implement an individualized physics course. These materials supplementing the capabilities of a good physics teacher could greatly enhance the effectiveness of the course.

PROCEDURES:

The Department of Science Education of Florida State University received a small grant from the regional office of the U.S. Office of Education during the 1971-72 academic year for this project. The primary effort in this project was the development and evaluation of supplementary materials for Unit 3, The Triumph of Mechanics, of the Project Physics Course so that this unit could be studied by beginning physics students on an independent basis. The concept of independent study applied to this project was the studying of physics by students without the resource of a teacher knowledgeable in physics. A proctor or program manager was selected to supervise the students participating in the study. The unit was

tried out in a representative high school physics class at the University School of Florida State University.

The supplementary materials developed for the unit were lesson guides, cassette tape recordings, flip-card presentations, chapter tests, and a management system. There were approximately seven lesson guides per chapter each covering one or two concepts within the chapter. (See sample in Appendix.) Cassette tape recordings were prepared to accompany each single concept film loop and each set of transparencies for the unit. Several short topics were semi-programmed on cards bound so that they could be "flipped" by the student on cue from a tape recording that narrated the topic. A system of record keeping was developed so that the proctor could easily monitor the progress of individual students.

The students were introduced to the procedure of studying Unit 3 of the Project Physics Course by a tape-slide presentation developed in the pilot project. The proctor, an FSU senior student in psychology, was introduced to the class as the manager who would be responsible for monitoring their progress, checking out materials and equipment, and maintaining all essential classroom records concerned with attendance, grading tests, etc. He was provided with appropriate instructions relating to general school policies. The proctor did not have any previous teaching experience. His content background was limited to high school physics and a college physical science course. Total control of the class was turned over to him during the experimental period.

Lesson guides were handed out to students one at a time. Each lesson had optional activities within it and also there were optional lessons within a given chapter. When a lesson was completed, the student requested the self-evaluation form from the proctor. At this time he checked off the assignments completed on a time accounting sheet and entered the date he requested the self-evaluation. Upon completing the self-evaluation exercise, the student made the decision to either restudy the lesson or advance to the next assignment. When a set of lesson guides representing a chapter of the Project Physics Course was completed, an end of chapter test covering the objectives listed in the basic set of lesson guides was administered to the student. The tests were composed of multiple choice and other items requiring short written answers. Chapter tests were scored by the proctor according to keys made available only to him. Individual student grades were determined on the basis of a combination selected by the student of test scores, optional lessons completed, and the time required to complete the chapter.

A time accounting sheet served as a record of the options elected by the student as well as a listing of the completed activities which were required. The individual time accounting sheets were maintained in folders available to the students at all times. Each student kept a log of his activities, reading notes, analysis of experiments, and solutions to problems. The log or notebook was periodically submitted to the proctor at his discretion for verification of entries on the time accounting sheet.

The physics classroom where the pilot project was implemented contained carrels equipped with audio-visual materials. Arrangement of the work areas was very flexible allowing moveable tables which could be set up in ways suitable to the students' needs and/or moods. Laboratory equipment was arranged in kit form and made available to students by request. Additional instruction in the form of

hand out sheets and tape-flip card presentations were prepared in order to facilitate the use of the equipment.

Twenty different cassette audio-tapes were prepared to accompany the film loops used in Unit 3 of the Project Physics Course. The tapes were stored on shelves, along with the film loops, in carrels equipped with appropriate projectors. Ten cassette audio-tapes were prepared to accompany transpariencies for Unit 3. Five tape-flip card presentations were produced concerning derivations of physical relationships and instructional procedures for laboratory exercises.

Evaluation of the Pilot Study

Both formative and summative evaluation techniques were used, formative for identifying areas needing revision and summative for comparing the achievement of students in the content of Unit 3 of the Project Physics Course with a national sample.

During the initial development of materials, formative evaluation information was obtained by having two students work through the lessons as they were first written. The students were closely observed by project staff members as they worked through the materials. Revisions based on the performance of the students, comments by the students, and observations of staff members were made before the materials were piloted in a regular class. This technique proved to be a valuable aid in identifying the errors and deficiencies in the first draft of the materials.

When the revised materials were piloted in the trial physics class the proctor used a small cassette tape recorder to record the vocal interactions and/or questions occurring between himself and students. The purpose of this recording related to an attempt to gather evidence on the nature of comments arising from students which would indicate needs for additional media, a need for physics knowledge on the part of the proctor, or needs for more adequate instructional procedures. The final revision of the materials attempted to overcome any need for a proctor knowledgeable in physics and to make the materials themselves truly independent of such a need.

The summative evaluation was based on the Unit Tests developed by the Harvard Project Physics staff for the Project Physics Course. At the beginning of the pilot program, students of the experimental class were administered test C (an entirely multiple choice version) for Unit 2. This was given to establish the entering behaviors of the students and to determine if the experimental class was a representative high school physics class. The students had completed the study of Unit 2 under the direction of a qualified physics teacher. Thus, it was possible to compare the performance of the experimental class having regular instruction in the Project Physics Course Unit 2 with a national sample. For each item of test C on any unit of the Project Physics Course, the teacher's handbook lists the proportion of the national sample correctly answering the item. The results of this test showed that on the 40 item test for Unit 2, the experimental group scored above the norm given by Project Physics on 21 of the items and below the norm on 19 items. On overall achievement, the class averaged 63.2% correct while the norm given was 67.4%. From these results there was no reason to believe the class was not a representative Project Physics class.

At the end of Unit 3 the experimental class was again tested using the Unit 3 test C. An item analysis was performed to evaluate the program and to provide information for revision in the formative evaluation of the materials. The experimental group scored higher than the norm given on the Project Physics test C scoring key on 24 of the 40 items and lower on 16 of the items. The class averaged 64 correct on the test as a whole compared with 61 given as the norm. The students performed slightly below the national norm on the Unit II test, after their study of Unit II, under the direction of a qualified physics teacher. The same students performed above the national norm on the Unit III test after their study of Unit III independent of the physics teacher and using the supplementary materials for Unit III developed in this project. The results on these achievement tests indicate that students can learn the content of the Project Physics Course with the aid of supplementary materials modeled in this project, without the help of a properly qualified physics teacher and achieve as well as the average student in a teacher-taught class.

An opinion survey was made after the students had been using the experimental materials for about one and one-half weeks and again when they finished the unit. The results of this gave both an over all reaction to the materials and method and a ranking of the relative value of each classification of materials developed. (See Appendix.)

The survey showed that the overall reaction of the class to the general format of the materials and related usefulness to their studies did not appreciably change during the tryout of the program. Rankings assigned to the importance of the features unique to the lesson guide did not change; the resource guide was rated as being the most helpful.

In terms of the Project Physics media for Unit III as supplemented by the materials developed in this project the initial survey rated the text as most valuable. The second survey rated the transparencies as most valuable, which certainly indicates the success of the manner in which the transparencies were incorporated into the instructional scheme. Film loops and laboratory activities were given the lowest rank in both surveys.

Responses to items concerning the various features of the lesson guide rated the self-evaluation quizzes and resource guides about equal as the most helpful parts of the lesson guides. The objectives stated for each lesson were given a slightly lower rating. The overview statement introducing each lesson was given the lowest rating.

Responses to items pertaining to the students' opinions about the independent method of study as compared to a conventional class taught by a qualified teacher indicate a preference for the latter. The experimental class was taught Units I and II by a qualified physics teacher prior to the beginning of the pilot program and quite naturally would be biased on this respect.

RESULTS:

(1) Students mean performance was near the national norm on tests over previous units of the Project Physics Course and could study independently Unit III of Project Physics with the aid of supplementary materials without the assistance of a qualified physics teacher and performed slightly above the national norm on the test for Unit III.

(2) Students ranked the media used in the program for Unit III of the Project Physics Course as supplemented with the materials developed in this project in descending order as follows: transparencies, text, Study Guide Problems, film loops, laboratory experiments.

(3) Students ranked the various features of the lesson guides developed in this project for Unit III of the Project Physics Course as follows: self evaluation quizes and resourse guide about equal and the most helpful, then the lesson objectives as next and the overview statement as the least helpful.

(4) Students preferred a class taught by a quallified physics teacher over the independent study approach when responding to the opinion survey.

CONCLUSIONS:

The supplemental materials to accompany Unit III of the Project Physics Course were developed and tried in a regular classroom. The results suggest that the Project Physics Course using supplemental materials similar to those developed in this project can be implemented for independent study and students will achieve as well as if they studied the course under the direction of a qualified physics teacher.

A proposal was developed and a draft copy was submitted to the Director of Research of the Regional Office of the U.S. Office of Education for funds to develop supplementary materials to accompany all units of the Project Physics Course for its implementation for independent study. The proposal is in the final draft stage and will be submitted for funding.

All three objectives as outlined in the introduction of this report were thus attained.

APPENDIX A

Opinion Survey

Independent Study Project Physics Course
Opinion Survey

The lesson guides have four parts, an overview statement of the content of the lesson, the objectives of the lesson, a resource guide and a self evaluation quiz. For each part as listed below are sets of opposite adjectives which may describe your feeling toward that part. Place an X with a pencil on the blank which indicates the degree to which one of the adjectives describes your feeling. (Refer to the accompanying lesson guide.) Please consider each pair separately. There are no patterns for responses.

1. The overview statement at the beginning of the lesson guide.

A.	Useless	_ _ _ _ _	Helpful
B.	Interesting	_ _ _ _ _	Dull
C.	Clear	_ _ _ _ _	Confusing
D.	Worthless	_ _ _ _ _	Valuable
E.	Important	_ _ _ _ _	Unimportant
F.	Wasteful	_ _ _ _ _	Productive
G.	Easy	_ _ _ _ _	Difficult
H.	Mysterious	_ _ _ _ _	Understandable

2. The objectives stating what you should be able to do at the end of the lesson.

A.	Valuable	_ _ _ _ _	Worthless
B.	Clear	_ _ _ _ _	Confusing
C.	Hard	_ _ _ _ _	Easy
D.	Wasteful	_ _ _ _ _	Productive
E.	Boring	_ _ _ _ _	Exciting
F.	Understandable	_ _ _ _ _	Mysterious
G.	Unimportant	_ _ _ _ _	Important
H.	Complex	_ _ _ _ _	Simple

3. The resource guide indicating the things to do in studying the lesson.

A.	Cluttered	_ _ _ _ _	Organized
B.	Productive	_ _ _ _ _	Wasteful
C.	Worthless	_ _ _ _ _	Valuable
D.	Mysterious	_ _ _ _ _	Understandable
E.	Important	_ _ _ _ _	Unimportant
F.	Effective	_ _ _ _ _	Ineffective
G.	Confusing	_ _ _ _ _	Clear
H.	Complex	_ _ _ _ _	Simple

4. The Self Evaluation Quizzes

A. Useful	_ _ _ _ _	Useless
B. Simple	_ _ _ _ _	Complex
C. Worthless	_ _ _ _ _	Valuable
D. Important	_ _ _ _ _	Unimportant
E. Confusing	_ _ _ _ _	Clear
F. Effective	_ _ _ _ _	Ineffective
G. Dull	_ _ _ _ _	Interesting
H. Wasteful	_ _ _ _ _	Productive
I. Easy	_ _ _ _ _	Difficult

5. Your overall opinion of the lesson guide.

A. Ineffective	_ _ _ _ _	Effective
B. Useless	_ _ _ _ _	Useful
C. Clear	_ _ _ _ _	Confusing
D. Complex	_ _ _ _ _	Simple
E. Valuable	_ _ _ _ _	Worthless
F. Understandable	_ _ _ _ _	Mysterious
G. Unimportant	_ _ _ _ _	Important
H. Successful	_ _ _ _ _	Unsuccessful

6. For each part of the lesson guides as they are listed below in pairs, select for each pair the one which was the most helpful in your study. For example, the pair, overview statement and objectives, if you feel that the objectives were more valuable then the overview statement, circle objectives.

A. Resource Guide - Objectives
B. Self Evaluation Quiz - Overview Statement
C. Resource Guide - Self Evaluation Quizzes
D. Objectives - Self Evaluation Quizzes
E. Resource Guide - Overview Statement
F. Objectives - Overview Statement

7. The following things were used to help you learn the material in Unit III of the Project Physics Course. The Text, film loops, transparencies, study guide problems, and laboratory activities. These are listed in pairs below. Select from each pair the one that was the most valuable in your study of the unit (as you did in question six).

A. Text - Film loops
B. Film loops - Study Guide Problems
C. Study Guide Problems - Laboratory Activities
D. Text - Transpariences
E. Transpariences - Laboratory Activities
F. Laboratory Activities - Text
G. Study Guide Problems - Text
H. Transpariences - Film loops
I. Study Guide Problems - Transpariences
J. Transpariences - Laboratory Activities

8. How would you compare the Independent Method of studying to the methods used previously?

A. Very much better.
B. Somewhat better.
C. No difference.
D. Somewhat worse.
E. Very much worse.

9. The Independent method of studying physics made physics . . .

A. very difficult to learn.
B. somewhat difficult to learn.
C. probably had the same amount of difficulty as any method.
D. somewhat less difficult to learn.
E. much less difficult to learn.

10. How do you feel about the independent study approach as it was employed in Unit III of the Project Physics Course?

A. A very valuable learning experience.
B. A reasonably satisfying learning experience.
C. Not much different than any other method of learning.
D. A somewhat disappointing learning experience.
E. A very disappointing learning experience.

11. Do you think this is a good way to study physics?

A. Yes B. No

The following is the same type of question as questions one through five. Please indicate the degree of your feeling.

12. Your overall opinion of the Independent Method of studying the Project Physics Unit III.

A.	Dull	_ _ _ _ _	Interesting
B.	Unique	_ _ _ _ _	Common
C.	Weary	_ _ _ _ _	Refreshing
D.	Understandable	_ _ _ _ _	Confusing
E.	Harder	_ _ _ _ _	Easier
F.	Risky	_ _ _ _ _	Sure
G.	Threatening	_ _ _ _ _	Comforting
H.	Safe	_ _ _ _ _	Dangerous
I.	Boring	_ _ _ _ _	Exciting
J.	Wasteful	_ _ _ _ _	Productive
K.	Joyful	_ _ _ _ _	Gloomy
L.	Efficient	_ _ _ _ _	Inefficient

APPENDIX B

Sample Lessons

Chapter 9 Lesson I Time: 1 day

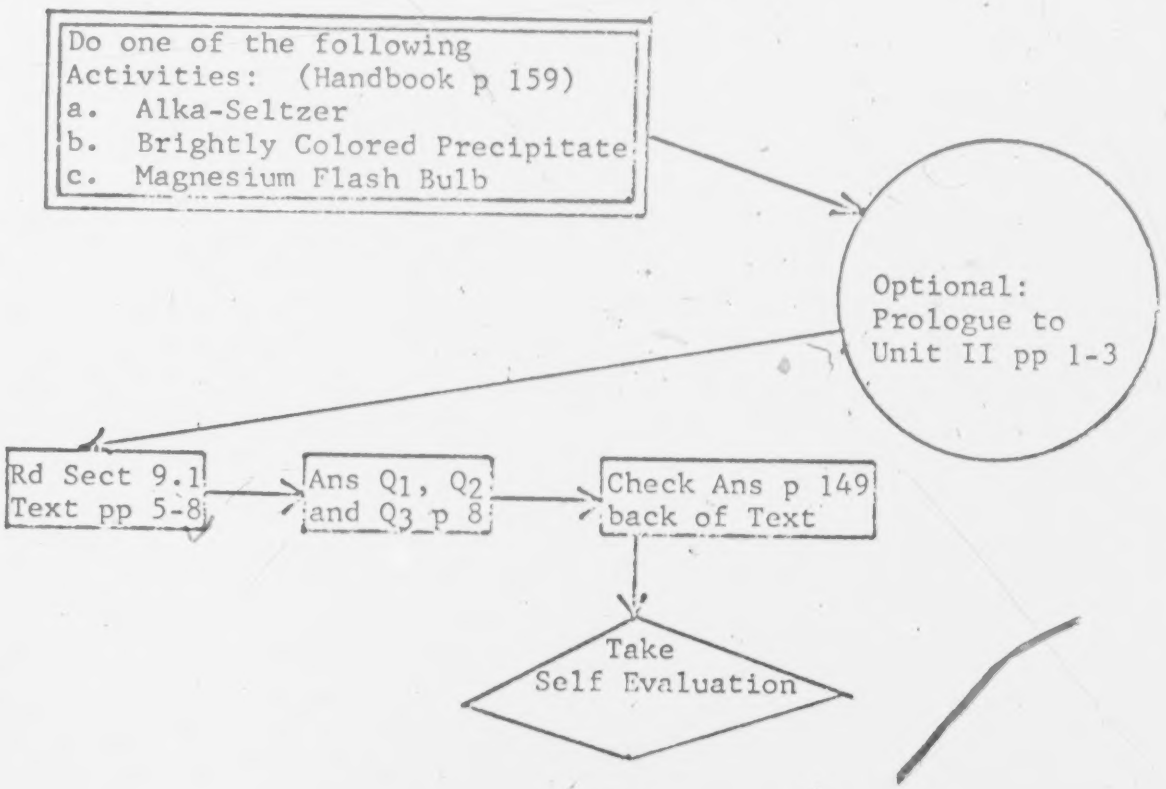
Conservation of Mass

Mass can be thought of as the quantity of matter in something. For centuries men have believed that the total amount of material in the universe remains constant (is conserved). Although modified slightly in certain reactions, this conservation law remains one of the basic laws of science.

OBJECTIVES. When this lesson is completed, you should be able to:

1. when given statements by Francis Bacon and Antoine Lavoisier, identify the statements which pertain to scientific principles that relate to the conservation of mass law.
2. compare the application of the conservation of mass law in open systems to closed systems.
3. when given a list of physical descriptions, identify the one which best describes mass.

RESOURCE GUIDE.



1. If 1 gram of hydrogen gas combines chemically with 8 grams of oxygen gas in a closed ystem, there will be ____grams of water produced.

   a. less than 9
   b. exactly 9
   c. more than 9

2. Mass is a

   a. force.
   b. volume
   c. quantity of matter.
   d. vector quantity

3. The total mass remains constant in

   a. an open system.
   b. a closed system.
   c. both case a and case b.
   d. neither case a nor b.

4. Select from the following statements those concerning the conservation of mass law.

   a. "All substances that exist now have existed in the past..."
   b. "...In all operations of nature, nothing is created; and each quantity of matter exists both before and after the experiment..."
   c. Volume is the fundamental unit of the quantity of matter.
   d. "...The sum total of matter remains unchanged without increase or diminution..."

Chapter 9 Lesson I Self Evaluation KEY

1. b
2. c
3. b
4. b and d

Chapter 9 Lesson IV (Optional) Time: 1 day

Conservation of Momentum in Two-Dimensions

You learned that momentum is conserved for "head-on" collisions. Since the moments vectors in this case always pointed along the same line, this type of collision was called one-dimensional. The law of conservation of momentum is general enough to apply in two or three dimensions, however. This lesson will be concerned with collisions in a plane or two-dimensional collisions.

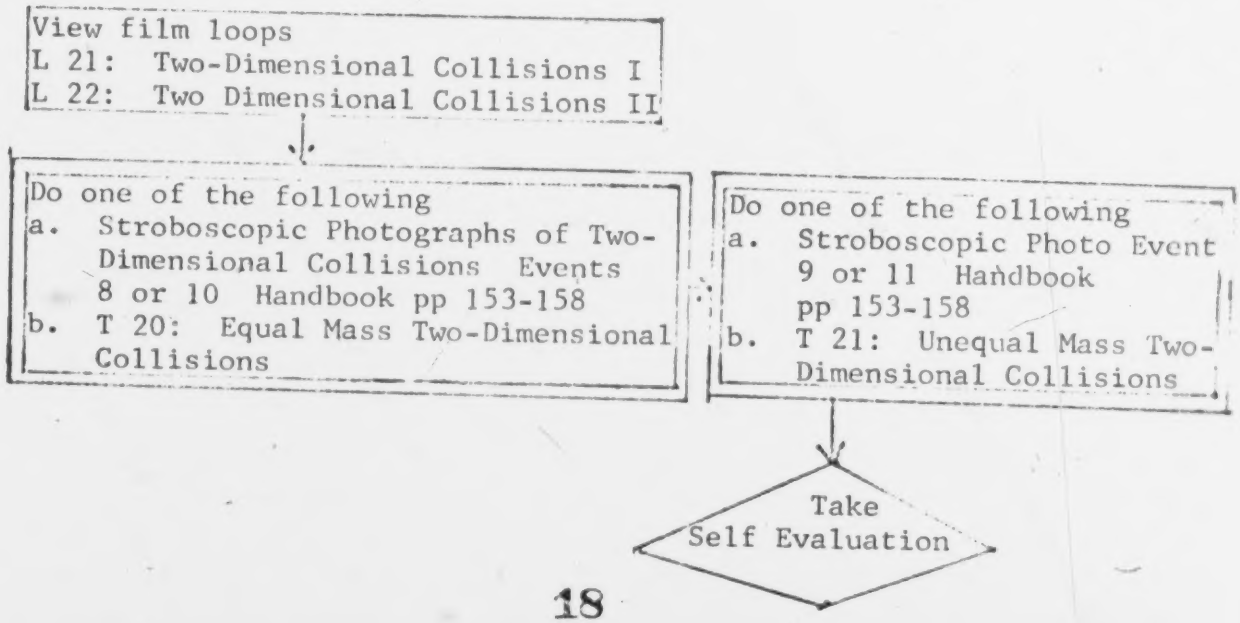
OBJECTIVES.

12. Given the masses and velocities of two objects colliding in a two-dimensional collision, be able to show that momentum is conserved.

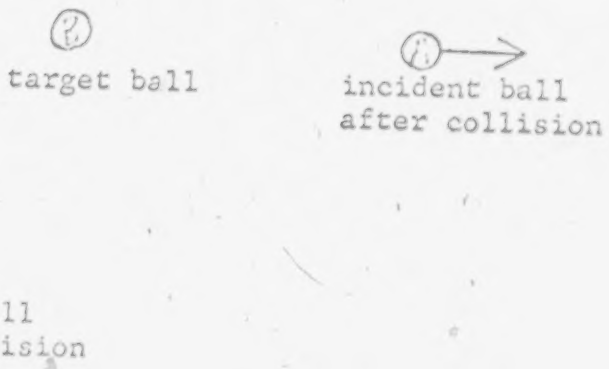
13. Given the total momentum of two balls before a two-dimensional collision occurs and the momentum of one of the balls after collision, be able to determine the magnitude and direction of the momentum of the other ball.

14. Given that two objects collide in a two dimensional collision determine any one unknown quantity (either mass or velocity) before or after collision if all other values for the masses and velocities are given.

RESOURCE GUIDE.


View film loops
L 21: Two-Dimensional Collisions I
L 22: Two Dimensional Collisions II
Do one of the following
a. Stroboscopic Photographs of Two-Dimensional Collisions Events 8 or 10 Handbook pp 153-158
b. T 20: Equal Mass Two-Dimensional Collisions
Do one of the following
a. Stroboscopic Photo Event 9 or 11 Handbook pp 153-158
b. T 21: Unequal Mass Two-Dimensional Collisions
Take Self Evaluation

A 1 kg billard ball (A) moving 5 m/sec in the direction shown in the drawing below strikes a ball (B) of equal mass and initially at rest. The collision is not "head-on" and ball (A) moves off as shown. Ball (A) has a speed of 3 m/sec after collision.



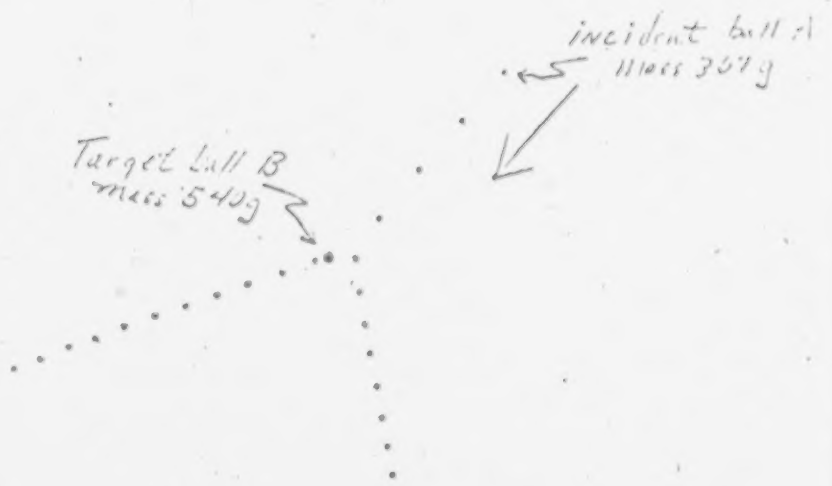
1. Ball B has a speed of 4 m/sec in the direction

a. ↓ b. → c. ← d. ↑ e. ↗

2. The magnitude of the total momentum of balls A and B after collision is:

a. 5 kg m/sec b. 4 kg m/sec c. 3 kg m/sec d. 0

3. The drawing at the right is adapted from a strobe photo where ball A moves toward ball B and collides with ball B. The flash rate is 20 per second. Prepare a drawing which shows the initial and final momentum vectors. Include on the drawing the resultant momentum after collision.



4. Which of the following are true about the drawing for problem 3?

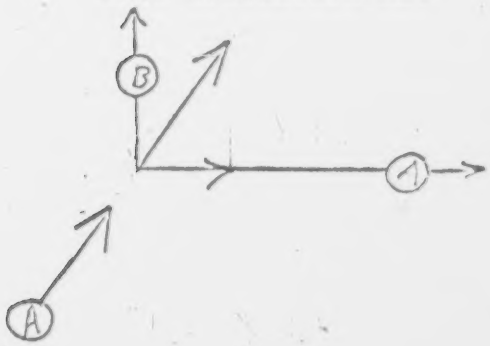
   a. Ball A moves slower after the collision.
   b. Ball B moves with increased speed after the collision has occurred.
   c. The magnitude of momentum of ball A after collision added to the magnitude of momentum of ball B after collision is equal to the magnitude of ball A before collision.
   d. The momentum of ball A before collision is equal to the total momentum of balls A and B after collision.
   e. All of the above statements are correct.

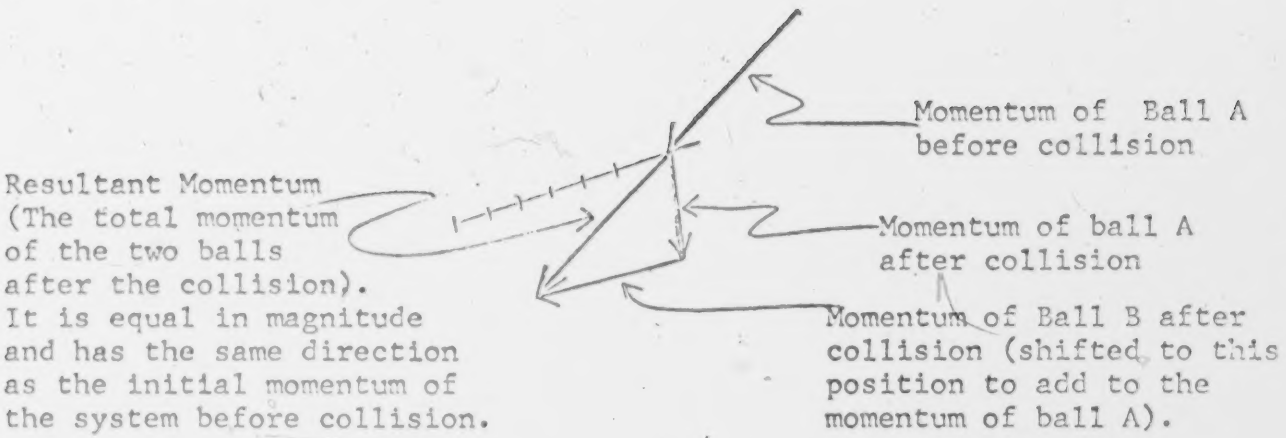
5. If the mass of ball A was doubled and the mass of ball B was doubled (referring to problem3)

   a. the directions of motion would be different after collision.
   b. only one ball could have moved faster after collision.
   c. the drawing would show the same directions as before.
   d. both b and c are correct.
   e. both a and b are correct.

Chapter 9 Lesson IV Self Evaluation KEY

1. d (see drawing #1)
2. a
3. see drawing #2
4. a, and d.
5. c




Momentum of Ball A before collision
Resultant Momentum (The total momentum of the two balls after the collision). It is equal in magnitude and has the same direction as the initial momentum of the system before collision.
Momentum of ball A after collision
Momentum of Ball B after collision (shifted to this position to add to the momentum of ball A).